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54 **Procedure and device for demodulation by sampling**

57 Procedure for demodulation of a signal, which consists of a modulated carrier, in which to obtain a base band signal from which the modulations in amplitude and/or in phase that are being determined can be derived, the signal to be demodulated is sampled at a frequency that is less than the frequency of the carrier and characterized in that in order to determine an amplitude and/or phase value of the modulated carrier, it is sampled by two successive pulses separated by a time that is an odd number of quarter periods of the carrier.

[see original for figure]

## Description

The present invention relates to a process and a device for demodulation by sampling.

It is especially advantageously used for receiving modulated ultrasound waves, e.g., in an ultrasound alarm system of the type used to protect automotive vehicles.

Classically, complex electronics having a large number of components are used for demodulation of a signal that is modulated in amplitude or in phase.

In general, such electronics particularly have an amplifier for the demodulated signal, making it possible to obtain a signal that can be processed by a standard microcontroller (8-bit analog/numeric converter of the type sold under the name Series 6800 by MOTOROLA, for example).

They could also contain a microcontroller that is able to sample the signal at high frequency (frequency close to MHz to obtain good resolution) and, in addition, having a very large memory capacity. In practice, analog demodulations at low frequencies are generally used upstream of the sampling.

These electronics have a high electrical power consumption. In addition, they are of significant cost and size.

The goal of the invention is to propose a process and a device for demodulation that makes it possible to remedy these inconveniences and to simplify the equipment used.

A process of demodulation is already known from FR 2 573 589, in which the sampling frequency is less than the frequencies of the signal to be demodulated and, in addition, is greater than double the length of the bands of the signal to be demodulated.

A device for processing a television signal is also known from EP 0 442 578, in which the intermediate frequency signal is scanned by a signal whose frequency is a sub-multiple of this intermediate frequency.

The invention itself proposes a procedure for demodulation of a signal which consists of a modulated carrier in which, in order to obtain a base band signal from which the modulations in amplitude and/or in phase that are being determined, the signal to be demodulated is sampled at a frequency that is less than the frequency of the carrier, characterized in that in order to determine an amplitude and/or phase value of the modulated carrier, it is sampled by two successive pulses separated by a time that is an odd number of quarter periods of the carrier.

The invention also involves a device for demodulation that implements this procedure.

It is advantageously used for ultrasound alarm systems, in particular for automotive vehicles.

Other characteristics and advantages of the invention will be seen from the description that follows. This description is purely illustrative and not limitating. It must be read with reference to the attached diagrams in which:

- Figures 1a and 1b represent the spectra of a signal before and after sampling by a signal with frequency greater than the spectral band occupied by the signal;
- Figures 2a and 2b represent the spectra of a signal before and after sampling by a signal with a frequency less than the actual spectral band of the signal;
- Figures 3a and 3b are similar to figures 2a and 2b for a sub-multiple sampling signal with the frequency of the carrier of the signal to be demodulated;
- Figures 4a to 4c illustrate a possible embodiment of the invention and represent, respectively, the carrier of the signal to be demodulated, a reference signal of which the frequency is the sampling frequency, as well as the sampling pulses that are used;
- Figure 5a to 5c illustrate e.g., a signal modulated in amplitude and in phase (figure 5a), the sampling point obtained (figure 5c) with the sampling pulses (figure 5b) corresponding to the embodiment illustrated in figures 4a to 4c;
- Figure 6 is a schematic representation of a device that conforms to a possible embodiment of the invention;
- Figure 7 is a representation, using a block diagram, similar to that in figure 6 for another possible embodiment.

The spectrum S of a signal to be sampled is shown in figure 1a.

It is known that the sampling of a signal has the effect of making its spectrum periodic in the space of the frequencies (convolution of a Dirac function with the signal processed).

Figure 1b represents the spectrum $S_{samp}$ of the signal corresponding to the spectral signal S sampled at frequency $f_{samp}$.

As can be seen in spectrum $S_{samp}$, the spectral recurrence period S of the initial signal corresponds, over the entire spectral range, to the sampling frequency $f_{samp}$.

Still, as is illustrated in figure 2a, the actual spectral band occupied by a signal generally does not extend up to the frequency of 0 Hz, the actual spectrum SR generally having a null component approaching the frequency of 0 Hz. In figure 2a, the lowest frequency of the spectrum SR is referenced with fmin, the highest frequency with fmax. Frequency f0, which is the mean frequency between the frequency fmin and the frequency fmax, is the frequency of the signal carrier.

If the sampling frequency is chosen so that it is less than the frequency fmin, the spectrum $SR_{samp}$ of the signal sampled is of the type as is illustrated in figure 2b: it is the sum of the different components of the spectrum 0 to N, each corresponding to a sampling recurrence.

As will be understood by referring to this figure 2b, by carefully choosing the sampling frequency, it is possible to obtain an initial band signal (corresponding to one of the components 0 to N), from which it is possible to deduce the modulations in amplitude and/or in phase being determined.

In a preferred embodiment, the sampling frequency $f_{samp}$ is chosen in such a way that it would be a sub-multiple of the frequency f0 of the carrier ($f0 = k.f_{samp}$ where k is a whole number).

The $k^{th}$ component of the signal spectrum after sampling is thus made up of two sub-spectra, of which one is centered around 0 Hz, the other being centered around the frequency 2.f0.

As a result, the original signal is precisely reduced to the initial band signal SBdB corresponding to the modulations determined.

This is illustrated in figures 3a and 3b for a value of k equal to 3.

In an implementation method that is particularly advantageous, the carrier and the sampling signal are synchronous (sampling frequency exact sub-multiple of the carrier frequency). In the absence of this synchronicity, in fact, a shift occurs in the initial band spectrum around zero and thus artificial additional frequencies which are a source of errors.

In addition, in a manner that is also preferred, the sampling frequency $f_{samp}$ is chosen so that it is greater than the length fmax-fmin of the spectral band actually occupied by the original signal. This makes it possible to prevent overlap between the spectral components corresponding to the different recurrences.

This thus prevents components from the spectrum from adding up to give a complex result which degrades the information carried by the original signal.

Reference is made to figures 4a to 4c, on which a possible embodiment of the invention is illustrated.

Figure 4a represents the carrier with frequency f0 of the signal to be demodulated.

This signal to be demodulated has, e.g., a band length ± F.

The sampling frequency is chosen so that it is greater than 2F. It is equal to f0/k, where k is very much less than f0/2F. Figure 4b shows square signal of which the frequency is the sampling frequency and which is synchronized with the carrier represented in figure 4a.

Thus, as has been illustrated in figure 4c, using this frequency signal $f_{samp}$, two pulses I1 and I2 are generated, separated by the time of an odd number of quarter periods of the carrier.

This time range is very much less than the period of the frequency reference signal $f_{samp}$ represented in figure 4b (d less than 4.k).

Thus, thanks to these successive pulses I1 and I2, two samples M1 and M2 are recorded, one at time n.k.T (T = 1/f0), the other at the time n.k.T + d.T/4.

As a result, these two pulses make it possible to measure the sine and co-sine components of the modulated signal.

Most particularly, the values of the two samples M1 and M2 are as follows:

$$M1(n.k.T) = A(n.k.T)\sin(2\pi 10.n.k.T + \phi(n.k.T))$$

and

$$M2(n.k.T + d.T/4) = A(n.k.T + d.T/4)\sin(2\pi_1 f0(n.k.T + d.T/4) + \phi(n.k.T + d.T/4)),$$

where A and $\phi$ are the amplitude and phase corresponding to the modulation, i.e.:

$$M1(n.k.T) = A(n.k.T)\sin(\phi(n.k.T))$$

and

$$M2(n.k.T + d.T/4) = A(n.k.T = K.T/4)\cos(\phi(n.k.T + D.T/4)).$$

Given that $d < 4.k$ and that the modulating signal is considered as a constant throughout the sampling period, it is possible to consider that the two following equalities are verified:

$$A(n.k.T) \# A(n.k.T + d.T/4)$$

and

$$\phi(n.k.T) \# \phi(n.k.T + d.T/4).$$

As a result, values M1 and M2 are processed by a calculation unit to which they are sent to recover the values of A and $\phi$ at the time n.k.T.

By way of example, in figure 5a, a signal has been represented:

- of which a first part, referenced with I, is not modulated and corresponds to the carrier with frequency f0, e.g., 40 kHz;
- of which a second part, referenced with II, corresponds to the same carrier modulated in amplitude;
- and of which a third part, referenced with III, illustrates a modulation of the frequency around the frequency of the carrier.

Values M1 and M2 obtained using this signal with the sampling pulses at the frequency of 400 Hz (k = 100, d = 10, F = 100 Hz), such as illustrated in figure 5b, have been carried over to figure 5c.

In figure 6, a method of implementation has been illustrated of an ultrasound alarm device that uses the procedure that has just been described.

This device has a microcontroller 1 of which the internal clock 1a (resonator with frequency of 2 MHz) is used to monitor an ultrasound transmitter 2, of which the frequency is 40 kHz. For this purpose, the clock output 1a of microcontroller 1 is connected to a divider that divides the frequency by 50, referenced with 3. This frequency divider 3 transmits a signal at a frequency of 40 kHz to a unit 4 which controls transmitter 2.

The ultrasound reflected by the environment in which the device is found are detected by a sensor 5, of which the output is sent to an amplifier 6. The signal processed by amplifier 6 is

sampled by microcontroller 1 (reaction 7) at a frequency of 400 Hz. The signals sampled are transmitted to a unit 8 for analog/numeric conversion at the input of microcontroller 1 (CAN 12 bits).

Values M1 and M2 of the samples thus recorded are processed by microcontroller 1 to determine the amplitude and the phase corresponding to these samples.

This information is then used to interpret the modulation of the signal received and to deduce the possible presence of an intrusion into the monitored environment.

It will be noted that, in this method of implementation, the sampling signal and the carrier are not necessarily synchronous since they are both generated by microcontroller 1.

A variation of an embodiment is illustrated in figure 7.

The device conforming to this variation also has a microcontroller 1, an ultrasound receiver 5, an amplifier 6, as well as an analog/numeric converter 8.

The ultrasound transmitter 2 is controlled by a frequency source 9 at 40 kHz. The internal signal of microcontroller 1 which controls the sampling pulses is synchronized with this frequency source 9.

For this purpose, one output of source 9 is sent to a divider 10 that divides the frequency by 100. The signal of 400 Hz at the output of divider 10 is sent to an analog input (with integrated analog-numeric converter) of microcontroller 1 in order to synchronize the internal control signal of sampling pulses.

It will be noted that the synchronization signal received from the source 9 must be a low frequency signal in order to make it possible for the microcontroller to recover it with good precision without having to use more complicated processing.

## Claims

1. Procedure for demodulation of a signal which consists of a modulated carrier in which, in order to obtain an initial band signal from which the modulations in amplitude and/or phase are deduced, the signal to be demodulated is sampled at a frequency that is less than the carrier frequency, characterized in that, in order to determine an amplitude and/or phase value of the modulated carrier, the carrier is sampled by two successive pulses separated by a time that is an uneven number of quarter periods of the carrier.

2. Procedure according to Claim 1, characterized in that the sampling frequency is a sub-multiple of the carrier frequency.

3. Procedure according to Claim 2, characterized in that the sampling frequency is greater than the spectral band length of the modulated carrier.

4. Device for demodulation of a signal which consists of a modulated carrier, characterized in that it has the means (1, 5 to 8) to sample the carrier modulated at a frequency that is less than the frequency of its carrier in such a way as to use the procedure according to one of the preceding claims.

5. Device according to Claim 4, in that it comprises the means (5, 6) for receiving the modulated carrier as well as a microcontroller (1) connected to the said means of reception, the said microcontroller (1) controlling the sampling of the signal received by the said means of reception (5, 6) and calculating the parameters for phase and/or amplitude modulation as a function of the sampling values received from the said means of reception.

6. Device according to Claims 4 and 5, in that it comprises the means (3, 10) for synchronizing the sampling means (1, 5 to 8) and a transmission source (4, 9) at the origin of the carrier of the signal to be demodulated, the sampling frequency being an exact sub-multiple of the carrier frequency.

7. Device according to Claims 5 and 6 taken in combination, characterized in that it comprises the means (3) to synchronize the transmission source (4) to a clock signal of the microcontroller (1).

8. Device according to Claims 5 and 6 taken in combination, characterized in that it comprises the means (3) to synchronize an internal signal of the microcontroller (1) with a transmission source (9).

9. Alarm system for detection by ultrasound, in particular for an automotive vehicle, having the means for transmission of ultrasound (2), the means (1, 5 to 8) for receiving reflected ultrasound and for detection of an intrusion as a function of modulation of the ultrasound received, characterized in that these means of reception and detection have a device according to one of Claims 4 and following.

[see original for figures]

FIG. 4a Key:

Porteuse = Carrier

FIG. 4b Key:

Signal de fréquence = Signal with frequency

$F_{éch} = F_{samp}$

FIG. 4c Key:

Impulsions d'échantillonage = Sampling pulses

FIG. 5b Key:

Impulsions = Pulses

FIG. 5c Key:

Echantillons = Samples

European Patent Office

# EUROPEAN RESEARCH REPORT

Application number

EP 96 40 0529

## DOCUMENTS CONSIDERED RELEVANT

| Category | Citation of the document with indication of the relevant parts | Claims involved | CLASSIFICATION OF THE REQUEST (Int. CL.5) |
|---|---|---|---|
| D,A | FR-A-2 573 589 (ZELLWEGER USTER S.A.)<br>* claim 1 *<br>---- | 1-4 | H 03D3/00 |
| D,A | EP-A-0 442 578 (PHILLIPS PATENVERWALTUNG GMBH)<br>* claims 1, 5 *<br>---- | 2, 6 | |
| A | EP-A-0 461 720 (N.V. PHILIPS GLOEILAMPENFABRIEKEN)<br>* document as a whole *<br>---- | 1, 2 | |
| A | EP-A-0 285 252 (BRITISH AEROSPACE PUBLIC LIMITED COMPANY<br>---- | | |
| | | | TECHNICAL AREAS RESEARCHED (Int. CL.5) |
| | | | H03D |

This report has not been established for all of the claims.

| Research location | Research completion date | Examiner |
|---|---|---|
| THE HAGUE | June 3, 1996 | Peeters, M. |

CATEGORY OF DOCUMENTS CITED

X: particularly relevant by itself
Y: particularly relevant in combination with another document in the same category
A: technology background
U: unwritten disclosure
P: inserted document

T: theory or principle on which the invention is based
E: document of a prior invention, but published on the date of application or after this date
D: cited in the request
L: cited for other reasons

&: member of the same family, corresponding document